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LOADPORT APPARATUS AND METHOD FOR USE THEREOF

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of and priority to U.S. Provisional Patent Application Serial No. 60/396,536 entitled "Thermal Processing System" filed July 15, 2002 and U.S. Provisional Patent Application Serial No. 60/428,526 entitled "Thermal Processing System and Method for Using the Same" filed November 22, 2002, both of which are hereby incorporated herein in their entirety.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] The present invention relates generally to semiconductor processing equipment. In particular, the present invention relates to a loadport apparatus and method for use in semiconductor processing equipment.

Description of Related Art

[0003] A large variety of processing equipment and apparatus are commonly used in the manufacture of integrated circuits (ICs) and semiconductor wafers. Such equipment is

typically located in a semiconductor fabrication facility ("fab") and the semiconductor wafers are transported throughout the fab to the appropriate equipment for processing. With advances in the industry, integrated circuits and semiconductor devices have become increasingly complex and typically include the fabrication of multiple layers of intricate devices and interconnects. The size of the devices have greatly decreased, thereby significantly increasing the number of devices fabricated on a single semiconductor wafers. As a result, the value of a semiconductor wafer increases substantially as a wafer progresses through the processing equipment in the fab.

[0004] Considerable care must be taken to reduce the risk of damaging and/or contaminating the wafers when moving semiconductor wafers through the fab and when transferring the wafers to and from processing equipment. Further, the wafers must be retained in a clean room environment and often must be processed in a controlled atmosphere. A batch of wafers are typically conveyed throughout the fab and to and from the processing equipment via a sealed front opening unified pod (FOUP) which is well know and highly standardized by the industry. The batch of wafers are housed in the interior of the FOUP which is typically maintained at a high level of cleanliness. While considerable care must be taken in the transport of wafers, speed and throughput are of utmost importance. Thus, the semiconductor industry has invested significant efforts in the development of wafer transfer designs and systems.

[0005] In certain applications, large numbers of wafers are processed together in large batches. For example, large vertical furnaces are often used for thermal processing of wafers to carry out thermal treatment such as heat treatment, anneal, diffusion or dopant

implantation. U.S. Patent No. 4,770,590 discloses one example of a large batch vertical furnace having a wafer transfer mechanism and a boat exchange unit. A cassette holder system 27 has a number of cassette support shelves 61 supported on a vertical rods 63, which in turn are operated by respective drive mechanisms 65 to facilitate the loading and unloading of cassettes into and out of the cassette holder system 27. A wafer transfer module mechanism 29 handles the transfer of finished wafers from the boat 39 to empty cassettes after processing, as well as the transfer of unfinished wafers from other cassettes to the boat 39 for processing. In such a large batch furnace, each process cycle usually requires a substantial amount of time, so the boat exchange unit 25 enables one boat 39 to be within the process chamber while wafers are transferred between the other boat 39 and the cassettes 37.

[0006] More recently, semiconductor processing equipment has been designed to process small batches of wafers. One example of such a "mini-batch" type system is described in detail in PCT patent application serial no. ______ (Attorney Docket no. FP-71748/MSS/WEN) filed simultaneously herewith, and claiming the benefit of U.S. Provisional Patent Application Serial Nos. 60/396,539 filed July 15, 2003 and 60/428,526 filed November 22, 2002, both of which are incorporated herein by reference in their entirety. The smaller number of wafers allow for faster transport between the FOUP and the processing equipment; however, the environment of the wafers in the FOUP and the environment in the processing equipment is typically different and providing for transfer of wafer in this situation requires complexity and time. A number of approaches to improve on transfer designs have been developed in the art. One example of a system is disclosed in U.S. Patent No. 6,428,262, directed to an ion implantation system, where the

transfer design has load locks that are collocated with a vacuum robot section 32, in an attempt to decrease the volume and optimizing operations undertaken throughout the travel distance between a FOUP and the ion implantation chamber 14. Throughput improvement is attempted when a group of wafers are moved from the FOUP by a first end effector and loaded into a load lock by raising the first end effector and by lowering a first load lock door of the load lock at a first atmosphere opened position (sec Abstract). The first load lock is then sealed to its sealed position by raising the first load lock door. The load lock is then evacuated; and a second load lock door of thc load lock is raised to a vacuum opened position. Finally, a 3-axis robot moves one of the wafers from the load lock to the ion processing chamber.

[0007] Unfortunately, potential semiconductor processing speed is limited by the number of times each wafer is moved between the FOUP 12 and ion processing chamber 14. Each movement adds additional time and increases the complexity of the semiconductor processing system. A loadport apparatus, particularly for batch processing, and method for use thereof, which facilitates improved wafer transfer speed and overcomes the above and other disadvantages of known loadports is needed.

BRIEF SUMMARY OF THE INVENTION

[0008] In one aspect, the present invention advantageously provides desired throughput in semiconductor processing equipment, such as a small batch vertical furnace system, without the use of multiple load lock systems of the prior art. The present invention provides transfer of wafers from a FOUP directly to a wafer carrier associated with the processing equipment. An isolated loadlock allows for isolated sealing and purging and

can be combined with a standard loadport. The combination can reduce the complexity and footprint of the system. The typical two-stage load-lock can be combined into a common loadport. This "load-lock" loadport of the present invention isolates two separate environments and is configured to match a first and second environment, such as for example the environment inside the FOUP and the environment inside the furnace. In another aspect of the present invention, pneumatic and/or electric control of the loadport is provided which promotes maintaining the air-tight environment within the FOUP, whether the loadport is in an open or closed position.

[0009] One embodiment of the present invention is directed to a loadport apparatus which facilitates the transfer of wafers from a FOUP to the processing equipment. In general, the loadport apparatus includes a platform, a housing, a loadport door, a loadport door seal and a conditioning system. The platform is configured for securably receiving the FOUP. The housing includes an opening to a second chamber. The housing is configured for sealably engaging the FOUP when the FOUP is secured to the platform. The loadport door includes a door access mechanism for opening the door of the FOUP. The loadport door is movable between an open position in which said opening is in direct communication with the second chamber, and a closed position. The loadport door seal supports selectively sealing the opening from the second chamber when the loadport door is in the closed position. A conditioning system is provided and in communication with the loadport apparatus. More specifically the conditioning system provides for conditioning a mini-environment chamber, said mini-environment chamber being defined by an the loadport door, the seal, the opening, and the interior of the FOUP when the loadport door is in the closed position, the loadport door seal is sealed, and the FOUP

door is open. A method of transferring a wafer from the FOUP to the processing equipment is also disclosed.

[0010] The loadport and method for use thereof has other features and advantages which will be apparent from or are set forth in more detail in the accompanying drawings, which are incorporated in and form a part of this specification, and the following Detailed Description of the Invention, which together serve to explain the principles of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. 1 generally illustrates a perspective view of a small batch vertical furnace system having four units, in accordance with one illustrative embodiment.

[0012] FIG. 2 generally illustrates a side plan view in accordance with FIG. 1 of one unit.

[0013] FIG. 3 generally illustrates a top view in accordance with FIG. 1 of one unit.

[0014] FIG. 4 generally illustrates a front plan view of the loadport in accordance with FIG. 2.

[0015] FIG. 5 generally illustrates a cross-sectional view of the loadport in accordance with FIG. 2.

[0016] FIG. 6 is a schematic view of a loadport apparatus including a FOUP coupled with a movable container mount, in accordance with one illustrative embodiment of the present invention.

[0017] FIG. 7 is a schematic view in accordance with FIG. 6 illustrating the loadport apparatus including a FOUP in sealed communication with the housing.

[0018] FIG. 8 is a schematic view in accordance with FIG. 6 illustrating the door access mechanism in an extended position.

[0019] FIG. 9 is a schematic view in accordance with FIG. 6 illustrating extending the door access mechanism and engaging a FOUP door.

[0020] FIG. 10 is a schematic view in accordance with FIG. 6 illustrating retracting the FOUP door access mechanism coupled with a removable door of the FOUP.

[0021] FIG. 11 is a schematic view in accordance with FIG. 6 illustrating a mini-environment chamber according to one embodiment of the present invention.

[0022] FIG. 12 is a schematic view in accordance with FIG. 6 illustrating a loadport door in an open position.

DETAILED DESCRIPTION OF THE INVENTION

[0023] An illustrative semiconductor processing equipment 100, in this example a small batch vertical furnace system, having the loadport apparatus of the present invention is shown in perspective view in FIG. 1, in a side plan view in FIG. 2, and a top view in FIG. 3. While the furnace system 100 is shown with four units 110, 120, 130 and 140, it will be appreciated that a system may have only one or any number of units, as desired. The units may be any type of processing unit and may be identical to one another, different

from one another, or a combination of both. In the illustrative embodiment, all of the units 110, 120, 130 and 140 are comprised of vertical batch furnace systems. While processing equipment described herein are small batch vertical furnace units, the invention is not limited to such, and may be employed with many other types of semiconductor processing equipment.

[0024] In this example, each unit includes a process chamber 111, 121, 131, 141, in which various thermal processes are carried out. Referring only to unit 110 an elevator 112 is used to move a wafer carrier 113 containing a plurality of semiconductor wafers into and out of the process chamber 111. As shown in Fig. 1, each of the other units 120, 130, 140 also include associated elevators (only 142 shown) and wafer carriers 123, 133, 143 for conveying wafers in and out of the respective process chambers 121, 131, 141. For simplicity, one unit will describe in detail and it is understood that such description is applicable to the other units. The term wafer is used broadly herein to indicate any substrate containing a plurality of integrated circuits, one or more flat panel displays, and the like. Wafers are transported between one or more FOUP and the units. As shown in Fig. 1 two FOUPs are associated with each unit. FOUPs 116, 118 are associated with unit 110, FOUPs 126, 128 are associated with unit 120, FOUPs 136, 138 are associated with unit 130, and FOUPs 146, 148 are associated with unit 140. Other arrangements and number of FOUPs may be used. FOUPs are well known and are highly standardized in the industry. The FOUP is generally a pod like shaped sealed container which houses a plurality of wafers in the interior of the FOUP. The FOUP has a FOUP door to allow access to the wafers. As FOUPs are well know, it is not described in further detail herein.

[0025] Referring to Fig. 2 wafers are transported between FOUP 118 and the wafer carrier 113 via a wafer transfer unit 114. The interior of the FOUP represents a first environment, and the general interior of the processing equipment (such as at the wafer carrier 113) represents a second environment. To facilitate wafer transport, the FOUP 118 is supported on a platform 119 coupled to the loadport 200. The loadport 200 (FIG. 2) is configured to securable received the FOUP. While the loadport 200 is visible in the side view it should be understood that each chamber 111, 121, 131, 141 has an associated loadport. An automated and/or manual process may be used to couple the FOUP 118 with the loadport 200. During wafer transport, the elevator 112 is lowered so that the carrier 113 is generally positioned opposite the FOUP 118 when mated to the loadport 200. According to one embodiment, the first environment (interior of the FOUP) is typically comprised of a volume of gas having a concentration of approximately 21% oxygen by volume, and the second environment (inside the processing equipment) is typically comprised of a volume of gas having a concentration of approximately 5ppm oxygen. Thus, it is shown that the environment within the FOUP is usually quite different from the environment the wafers are exposed to in the processing equipment. Of significant advantage, the present invention provides for conditioning the wafers, or allowing for exposure of the wafers from one environment to the other as needed during processing.

[0026] Referring to FIG. 4 a front plan view, and FIG. 5 a cross-sectional view, the loadport 200 is illustrated in more detail. Various sensors and control keys for the loadport 200 are omitted from FIG. 4 and FIG. 5 to preserve clarity, but are shown in the schematic drawings of FIG. 6 through FIG. 12.

[0027] The loadport 200 generally includes a housing 240, a loadport door 250, an loadport door seal 260, and a conditioning system 270. A mini-environment chamber 271 is defined by the loadport door 250, load port door seal 260, a FOUP seal 246, an opening 241, and an interior 213 of the FOUP 210 when the loadport door 250 is in the closed position 253, the loadport door seal 260 is sealed, and the FOUP door 211 is open. The conditioning system 270 includes a gas inlet port 273, a gas exhaust port 274, and is in communication with the mini-environment chamber 271 for conditioning the mini-environment chamber 271.

[0028] In the illustrated embodiment, the conditioning system 270 includes one gas inlet port 273 and one gas exhaust port 274 provided within the housing 240. However, one should appreciate that any number of gas inlet ports and any number of gas exhaust ports, may be configured and used as desired. Further, gas inlet ports and gas exhaust ports may be coupled with the movable loadport door 250, a recess 254, and/or the FOUP 210, as desired.

[0029] As illustrated in FIG. 4 and FIG. 5 the loadport door seal 260 is preferably a compression seal that engages the loadport door 250 and the housing 240 for selectively sealing the opening 241 from the second chamber 220. As illustrated in FIG. 5 the loadport door seal 260 seals the opening 241 from the second chamber 220. As illustrated in FIG. 9 the loadport door seal 260 is deflated and moved with the load port door 150 to an open position (FIG. 12). One should appreciate that any number of configurations may be used as a seal, including an inflatable seal.

[0030] As illustrated in FIG. 6 the FOUP platform 230 is configured for receiving and securing the FOUP 210. The FOUP platform 230 illustratively includes a pair of kinematic pins 231-1 and 231-2, a pair of position sensors 232-1 and 232-2 illustratively located adjacent to the kinematic pins 231-1 and 231-2, and a FOUP locking mechanism 233. One or more kinematic pins may be used for receiving the FOUP 210. One or more position sensors may be positioned adjacent to one or more kinematic pins for sensing the position of the FOUP 210. In the illustrated embodiment, three kinematic pins (only pins 231-1 and 231-2 are shown), corresponding with three kinematic pin sensors (only sensors 232-1 and 232-2 are shown) are included in the platform 230. Preferably, each kinematic pin sensor is positioned adjacent to a corresponding kinematic pin to determine if a FOUP 210 has been received. One should appreciate that any number and configuration of kinematic pins and/or kinematic pin sensors may be used within the teaching of the present invention.

[0031] As shown in FIG. 6, locking mechanism 233 is illustratively an angular latch that is received by FOUP 210, such that rotational actuation of the angular latch secures the FOUP 210 to the platform 230. One should appreciate that any configuration and number of locking mechanisms may be used as desired, and that locking mechanisms are typically defined by a specification corresponding to a given loadport.

[0032] As illustrated in FIG. 6, a moveable container mounting system 239 may be defined to include the platform 230, a platform base 234, and a dock actuation mechanism 237. The moveable container mounting system 239 secures the FOUP 210 to the platform 230, while locking mechanisms 242 (such as, for example FOUP clamps

242-2, and 242-2 illustrated in FIG. 4) engage corresponding pins (not shown) that project from the FOUP 210 to secure the FOUP 210 to the housing 240. The platform 230 is mounted on a platform base 234 to support movement of the FOUP platform 230 between two or more docking positions. A dock actuation mechanism 237 between the FOUP platform 230 and the platform base 234 supports the movement of platform 230. The docking positions as illustrated includes an undocked position 235 (FIG. 6) and a docked position 236 (FIG. 7). A dock sensor 238 may be used to sense the position of the FOUP platform 230. One should appreciate that any configuration for moving the FOUP platform 230 back and forth between the undocked position 235 and the docked position 236 may be used within the teaching of the present invention. According to one illustrative embodiment, the dock actuation mechanism 237 includes an air cylinder for actuating movement between the docking positions 235 and 236.

[0033] As illustrated in FIG. 7 the housing 240 includes an opening 241 to the second chamber 220. The second chamber 220 is generally defined herein as where processing takes place, such as a furnace environment; however, the second chamber is not necessary a processing chamber and may be any other chamber employed in the system. As illustrated by FIG. 6 and FIG. 7, the FOUP 210 transitions from an undocked position 235 to a docked position 236 adjacent the housing 240. One or more locking mechanisms 242 such as, for example, clamps 242-1 and 242-2 (FIG. 4) engage the FOUP 210 to ensure an air tight seal between FOUP 210 and the housing 240. According to one illustrative embodiment, the locking mechanism 242 is a pair of clamps that engage pins protruding from opposite sides of the FOUP 210 in proximity to a top surface of the FOUP 210. The locking mechanism 242 engage and bias the FOUP 210 toward the

housing 240. One should appreciate that other configuration and number of locking mechanisms 242 may be used within the teaching of the present invention . As illustrated in FIG. 7, the FOUP 210 is secured to the platform 230 and sealed with the housing 240.

[0034] According to one illustrative embodiment shown in Fig. 7, a FOUP seal 246 is positioned adjacent the opening 241 for sealing the FOUP 210 in the docked position 236. Locking mechanism 242 engage and bias the FOUP 210 toward the housing opening 241 such that the FOUP seal 246 seals the housing of the FOUP 210 with respect to the housing 240. One should appreciate that any configuration for engaging the FOUP 210 to the housing 240 in an airtight manner may be used. According to one illustrative embodiment, the FOUP seal is an o-ring seal residing in the housing 240.

[0035] Referring again to FIG. 7, a container engagement sensor 243 is mounted to the housing 240 and is used to determine if the FOUP 210 is engaged with the housing 240. One should appreciate that any configuration and number of container engagement sensors 244 may be used as desired.

[0036] As illustrated in FIG. 8 loadport door 250 is movable in any direction as desired between an open position (FIG. 12) and a closed position 253. When the loadport door 250 is in the open position, the opening 241 is in direct communication with the second chamber 220. The loadport door 250 includes a recess 254 containing the FOUP door access mechanism 255 and having sufficient room to store the FOUP door 211. As illustrated in FIG. 7, loadport door 250 is in the closed position 253 with respect to the opening 241 thereby sealing the second chamber 220 from the external ambient. Moving

the loadport door 250 to the closed position 253 and actuating the loadport door seal 260 seals the second chamber 220 from the opening 241.

[0037] Referring again to FIG. 8, the recess 254 of the loadport door 250 is adjacent to the opening 241 while the loadport door 250 is in the closed position 253. While the FOUP 210 is engaged with the housing, the FOUP door 211 is accessible through the opening 241. The FOUP door access mechanism 255 is extended from the recess 254 and engages the FOUP door 211 for opening and/or closing the FOUP door 211. According to one illustrative embodiment, the FOUP door access mechanism 255 is mounted within the recess 254 and is moved with the loadport door 250 between the open position 252 (FIG. 12) and the closed position 253 (FIG. 11). One of ordinary skill in the art will appreciate that within the scope of the invention other configuration for the FOUP door access mechanism 255 may be used for engaging the FOUP door 211, such as, for example a FOUP door access mechanism causes the FOUP door to retract into the FOUP.

[0038] As illustrated in FIG. 8 the FOUP door access mechanism 255 includes an illustrative latching assembly 256 having one or more turn keys such as a turn key 257, an alignment pin 258, and a sensor 259. The latching assembly 256 engages the FOUP door 211 through opening 241. One or more turn keys 257 are used to secure the FOUP door 211 to the FOUP door access mechanism 255. One or more alignment pins 258 are used to align the removable FOUP door 211 with respect to the latching assembly 256. One or more sensors 259 may be used to confirm the position of the removable door with respect to the latching assembly 256. According to one illustrative embodiment, a turn key pair 258 is used to engage the FOUP door 211 using a single actuation device capable

of twisting the pair of turn keys simultaneously between an engaging position and a releasing position.

[0039] The FOUP door access mechanism 255 is retractably extended from the recess 254 to engage the FOUP door 211 as illustrated in Fig. 9. As the FOUP door access mechanism 255 is extended the alignment pin 258 aligns the FOUP door 211 and latching assembly 256. The sensor 259 indicates the proximity of the removable door and the latching assembly 256. One or more turn key 257 are actuated to engage the FOUP door 211. The FOUP door access mechanism 255 retracts into the recess 254 along with the FOUP door 211 as shown in FIGs. 10 and 11. Opening the FOUP door 211 allows access to the interior 213 of the FOUP 210.

[0040] To condition the wafers, or to move the wafers from the first to the second environment, the interior 213 of the FOUP 210 is purged and this is typically performed while the loadport door 250 is in the closed position 253 (as shown in FIG. 11), loadport door seal 260 is sealed, and FOUP seal 264 is sealed. According to one illustrative embodiment, the FOUP 210 (such as FOUP 118) is secured to the housing 240 of a wafer processing apparatus that typically includes a second chamber 220. FOUP 210 is secured to the housing 240 about the opening 241, using for example the FOUP seal 264. FOUP 210 is opened after the FOUP 118 is in sealed engagement with the housing 240 about an opening 241. Opening the FOUP door 211 is performed by extending the FOUP door access mechanism 255 through the opening 241 to engage and open the FOUP door 211. Opening the FOUP door 211 includes coupling the FOUP door access mechanism 255 with a removable FOUP door 211 and retracting both the FOUP door access mechanism

255 and the removable FOUP door 211 into a recess defined within the loadport door 250.

[0041] According to one illustrative embodiment, after the FOUP door is open, the mini-environment chamber is purged by dispensing a first gas into the mini-environment through a gas inlet, and discharging the first gas from the mini-environment through a gas outlet. According to one illustrative embodiment, the mini-environment chamber is defined for gas flow through one or more gas inlets 273, through a portion of the interior 213 of the FOUP 210, and through one or more gas outlets 274.

[0042] Alternatively, the mini-environment chamber 271 is conditioned by a purge gas entering the mini-environment chamber 271 through a gas inlet port 273. The purge gas and undesirable material are discharged through the gas outlet port 274 with any undesirable material, such as, for example, oxygen, moisture, and particulate material. The amount of purge gas expended is determined in part by the size of the chamber. Advantageously, the mini-environment chamber 271 provides a smaller chamber that typically consumes less purge gas during a purging process.

[0043] According to one illustrative embodiment, the loadport door 250 is opened by unsealing the loadport door seal 260 and then moving 251 the loadport door 250 from the closed position 253 (FIG. 11) to an open position 252 (FIG. 12) to support communication between the interior 213 of the FOUP 210 and the second chamber 220 through the opening 241. Accordingly, a wafer 212 contained within the FOUP 210 may be moved from the FOUP 210 into the second chamber 220. After processing, the wafer

is moved into the same FOUP or into another FOUP. According to one illustrative embodiment, the wafer is subsequently be placed in another FOUP such as for example FOUP 116.

[0044] The loadport door 250 is closed by moving the loadport door 250 from the open position 253 (FIG. 12) to a closed position 252 (FIG. 11) and sealing the loadport door seal 260 to seal the opening 241 from the second chamber 220. Closing the FOUP door 211 is performed by extending the FOUP door access mechanism 255 through the opening 241 to return the FOUP door 211 to the FOUP 210. According to one illustrative embodiment, closing the FOUP door 211 involves extending both the FOUP door access mechanism 255 and the FOUP door 211 from the recess 254 defined within the loadport door 250, closing the FOUP door 211 to the FOUP 210, releasing the FOUP door 211 from the FOUP door access mechanism 255, and retracting the FOUP door access mechanism 255 into the recess 254. FOUP 210 then is released from the housing 240 and the FOUP platform 234.

[0045] The foregoing descriptions of specific embodiments of the present invention have been presented for purposes of illustration and description. They are not intended to be exhaustive or to limit the invention to the precise forms disclosed, and obviously many modifications and variations are possible in light of the above teaching. The embodiments were chosen and described in order to best explain the principles of the invention and its practical application, to thereby enable others skilled in the art to best utilize the invention and various embodiments with various modifications as are suited to

the particular use contemplated. It is intended that the scope of the invention be defined by the Claims appended hereto and their equivalents.